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Technical Note 398

A Mass Spectrometer Method for Determining Percent-Range Helium in Gaseous Mixtures

By Philip W. Holland
November 1996

U.S. Department of the Interior

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ABBREVIATIONS AND SYMBOLS USED IN THIS REPORT

A	ampere
°C	degree Celsius
cm	centimeter
g	gram
GΩ	gigohm
h	hour
He	helium
ID	inside diameter
K	degree Kelvin
kΩ	kilohm
kPa	kilopascal
MΩ	megohm
µA	microampere
µF	microfarad
µH	microhenry
µL	microliter
mL	milliliter
mV	millivolt, direct current
min	minute
Ω	ohm
OD	outside diameter
ppm	part per million
Pa	pascal
pct	percent
pF	picofarad
sec	second
Vdc	volt, direct current
Vac	volt, alternating current
W	watt

A MASS SPECTROMETER METHOD FOR DETERMINING PERCENT-RANGE HELIUM IN GASEOUS MIXTURES

by Philip W. Holland[1]

ABSTRACT

The Bureau of Land Management's Helium Operations office in Amarillo, Texas, has developed a mass spectrometer method to determine percent-range helium in gaseous mixtures. Activated coconut charcoal at liquid nitrogen temperature is used to adsorb components other than helium in the mixture. A modified helium leak detector mass spectrometer is then used to detect the resulting helium "pressure peak." The digitized peak of the unknown sample is compared directly to that of a high-purity helium calibration standard. This method has been demonstrated to be accurate to within ±0.1 pct over the concentration range of about 30 to 100 pct helium.

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ACKNOWLEDGMENT

The author expresses his sincere thanks to Mr. Charles A. Seitz, chemist (retired), Helium Operations, for his assistance in designing and assembling the electronic circuits that are described in the appendix.

INTRODUCTION

The adsorptive property of activated charcoal was first discovered by Dewar (1)[2] in 1875. In 1906, Cady and McFarland (2) utilized activated coconut charcoal at liquid air temperature to adsorb components other than helium from a sample of natural gas. Using this technique, they were the first to discover the existence of helium in natural gases. A sample of natural gas they obtained from a well located near Dexter, Kansas, was found to contain approximately 2 pct helium.

Beginning in the mid 1930s, the U.S. Bureau of Mines (now defunct) developed several methods which utilized the adsorptive property of liquid-nitrogen-cooled coconut charcoal to determine helium in gaseous samples (3-5). These methods required corrections for pressure and temperature when measuring the volume of helium that remained after gas adsorption. Frequent calibrations with weighed primary standards (6,7) were required to obtain accurate results.

In 1970, Emerson and Kaplan (8) developed an improved apparatus and method for determining percent-range helium in natural gases and gaseous mixtures. The accuracy of this method is ±0.04 pct. It was developed out of the need to accurately measure the helium content in crude helium (about 70 pct helium) being purchased from private industry and stored in Bush Dome in the Cliffside gasfield under the Helium Conservation Program (9). This method is is still in use today to accurately measure the helium content of crude helium being stored for privately owned companies that have contracts with the Bureau of Land Management.

The Emerson/Kaplan method simplifies the measurement calculations by eliminating the need to correct the helium volume for temperature and pressure as required by the earlier methods. Activated coconut charcoal maintained at liquid nitrogen temperature (77 K) is used to adsorb all gaseous components except helium and neon, the neon being negligible. The helium pressure resulting from the "injection" of a 7-mL volume of unknown sample is measured using an electronic transducer and then compared to the pressure resulting from the injection of the same volume of pure helium standard. Injections of the sample and standard are performed under the same conditions. With the Emerson/Kaplan method, 20

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[2] Underlined numbers in parentheses refer to the list of references at the end of this report.

sample analyses can be performed in an 8-h workday. Reactivation of the charcoal in the trap is required after completing 10 sample analyses and is accomplished by allowing the trap to warm to room temperature and then heating it at 200° C for 5 min while under vacuum.

The method described in the present report also utilizes a liquid-nitrogen-cooled coconut charcoal trap to adsorb gaseous components from the sample. However, instead of using a pressure transducer to measure the remaining helium, a modified helium leak detector mass spectrometer having a continuously pumped vacuum system is used to detect the helium "pressure peak" as pumpout occurs. The digitized peak resulting from the injection of a 0.1-µL volume of unknown sample is then compared to that of the pure helium standard.

Although the mass spectrometer method is not quite as accurate as the Emerson/Kaplan method, it is considered an improvement because 30 sample analyses can be performed in an 8-h workday without the requirement for reactivation of the charcoal adsorbent after every 10 analyses. The mass spectrometer method presently serves as the "back-up" for the Emerson/Kaplan method.

MASS SPECTROMETER SYSTEM

A schematic diagram of the mass spectrometer system is shown in Figure 1. The system consists of a modified Consolidated Electrodynamics Corporation[3] model 24-120A helium leak detector mass spectrometer, an inlet system utilizing two chromatographic valves, and a liquid-nitrogen-cooled charcoal trap. A Hewlett Packard model 3390A programmable reporting integrator and model 19400A event-control module are used to automate valve switching and to quantify electrometer output.

The essential components of the inlet system shown in Figure 1 include the pure helium standard inlet port (A), sample inlet port (B), rotameter (C), stream-switching valve (1), sample injection valve (2), and air-switching solenoid valves (4, 5, and 6). Inlet ports A and B are Cajon Ultra-Torr male connectors with Viton O-ring seals. The helium standard and sample gas are admitted to the ports via 0.11-cm-ID by 120-cm-long stainless steel lines. Valve 1 is a Bendix model C-4, 8-port, sliding-piston-type chromatographic valve with Buna-N O-ring seals. Valve 2 is a Valco model ACI4WM.1, 4-port, rotor-type chromatographic valve with a 0.1-µL-capacity internal sample chamber. The rotor sealing material is Valcon M. The valves are actuated by compressed air (170 kPa) supplied through the three-way solenoid valves 4, 5, and 6 (Allied Control, model 31382). Solenoid valve 7 is used to divert gas flow from the sample valve prior to sample injection,

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[3] Reference to specific manufacturers and tradenames does not constitute endorsement by the U.S. Department of the Interior.

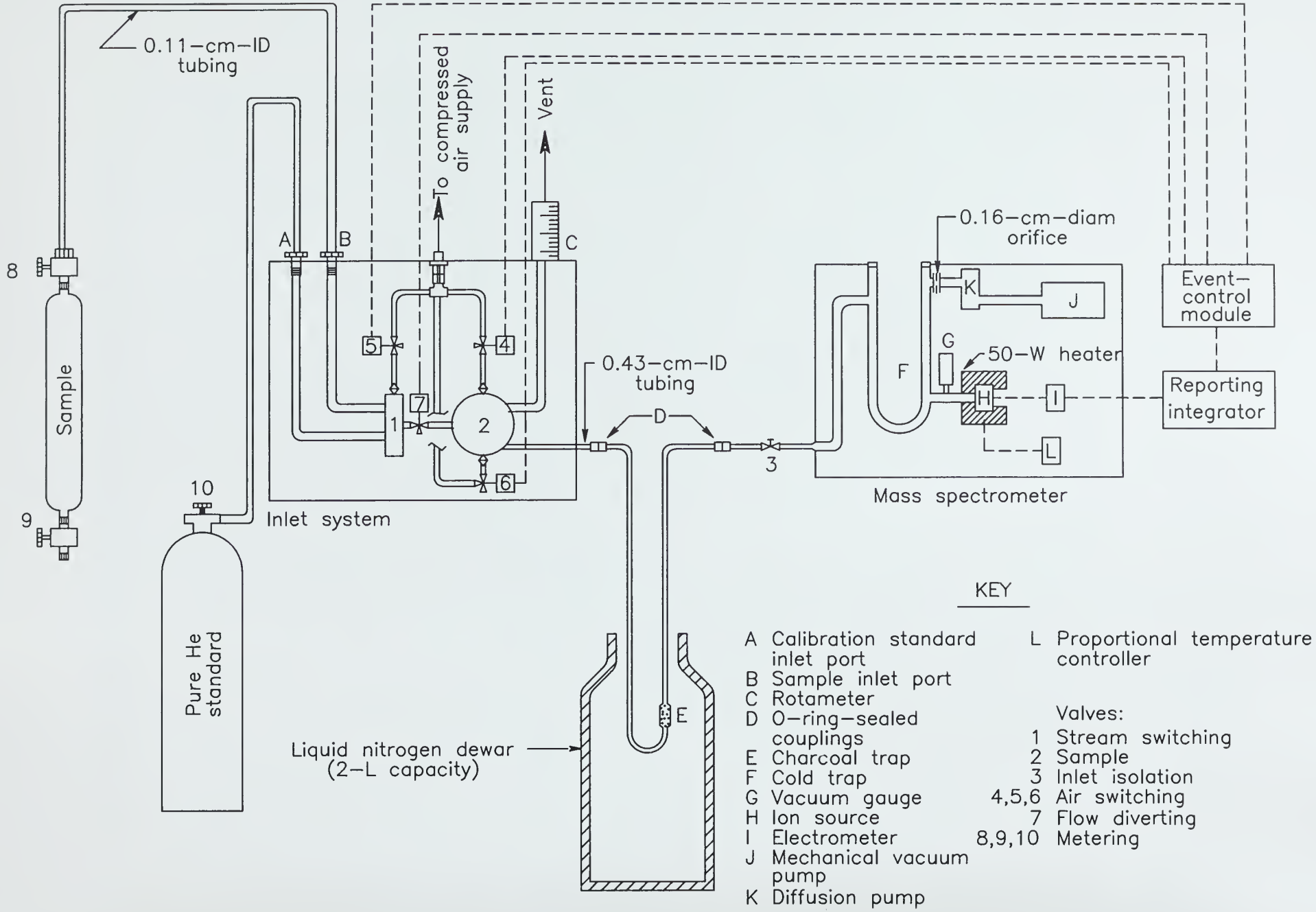

FIGURE 1. – Simplified drawing of modified CEC 24–120A helium leak detector mass spectrometer system.

thereby stopping gas flow through the sample chamber and allowing the gas pressure in the chamber to "bleed" to atmospheric. The gas flow pattern through valves 1 and 2 is shown in detail in Figure 2.

Valve sequencing and switching are accomplished using the programmable integrator and event-control module. The sequencing of the valves' operations provides for a standard-sample-standard series of analyses. The temperature of valves 1 and 2 is allowed to "float" with the ambient temperature; however, their rate of temperature change is minimized by insulating them with a 10-cm-thick layer of glass wool. Measurement of the valve's temperature drift after instrument warmup showed the change to be less than 0.2° C/h. Since the standard-sample-standard analysis series is completed in 12 min, the temperature of the valves is essentially constant during this period.

The mass spectrometer is connected to the sample inlet system through charcoal trap E (Figure 1). The trap is a 0.64-cm-OD (0.10-cm wall) by 56-cm-long stainless steel U-tube with a 0.95-cm-OD (0.10-cm wall) by 5-cm-long "bulb" about 3 cm from the base. The "bulb" contains approximately 2 g of 40/60 mesh activated charcoal (Alltech Associates). The charcoal is held in place with stainless steel wool packing.

The mass spectrometer itself is a 1-cm radius, 180°, permanent magnet instrument tuned for mass 4. The ion source temperature is regulated at 75.0±0.1° C using an external 50-W mantle heater (Briscoe Manufacturing) and a laboratory-built proportional temperature controller (10). The mass spectrometer's original electrometer and ion-source control circuits were replaced with the laboratory-built, solid-state circuits that are described in the appendix. These circuits were installed to improve the overall stability of the instrument.

Helium detection with the mass spectrometer is performed while the ion source is being pumped by the vacuum system (dynamic mode); therefore, precise control of the pumping speed is essential. To achieve this control, the line voltage supplied to the diffusion pump heating element is regulated at 105±0.01 Vac using a Sorensen model 1001 voltage regulator. The 0.16-cm-diameter orifice installed between the mass spectrometer's cold trap and diffusion pump intake (Figure 1) results in a reduced pumpout rate for helium, which produces a more symmetrical helium "pressure peak." The improved peak shape results in a more consistent start-of-peak detection by the integrator. The signal heights of the "pressure peaks" are measured, digitized, and recorded by the integrator.

A photograph of the mass spectrometer system is shown in Figure 3.

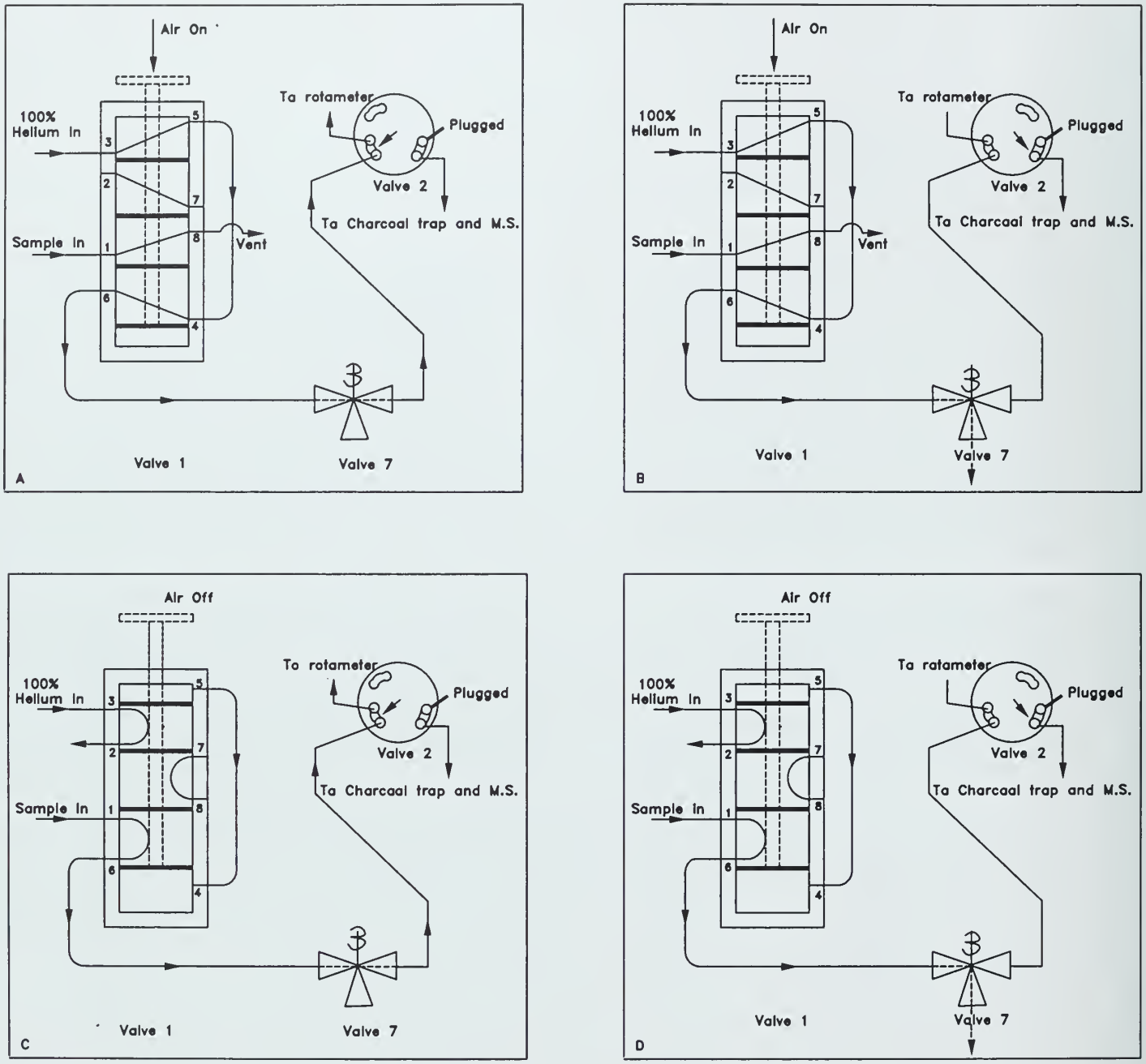

FIGURE 2. – Schematic of gas flow pattern through stream–switching and gas–sampling valves. A, Purging sample chamber with helium standard; B, Expansion of helium standard; C, Purging sample chamber with sample gas; D, Expansion of sample gas. (Numbers at valve ports correspond to the manufacturer's numbering of ports.

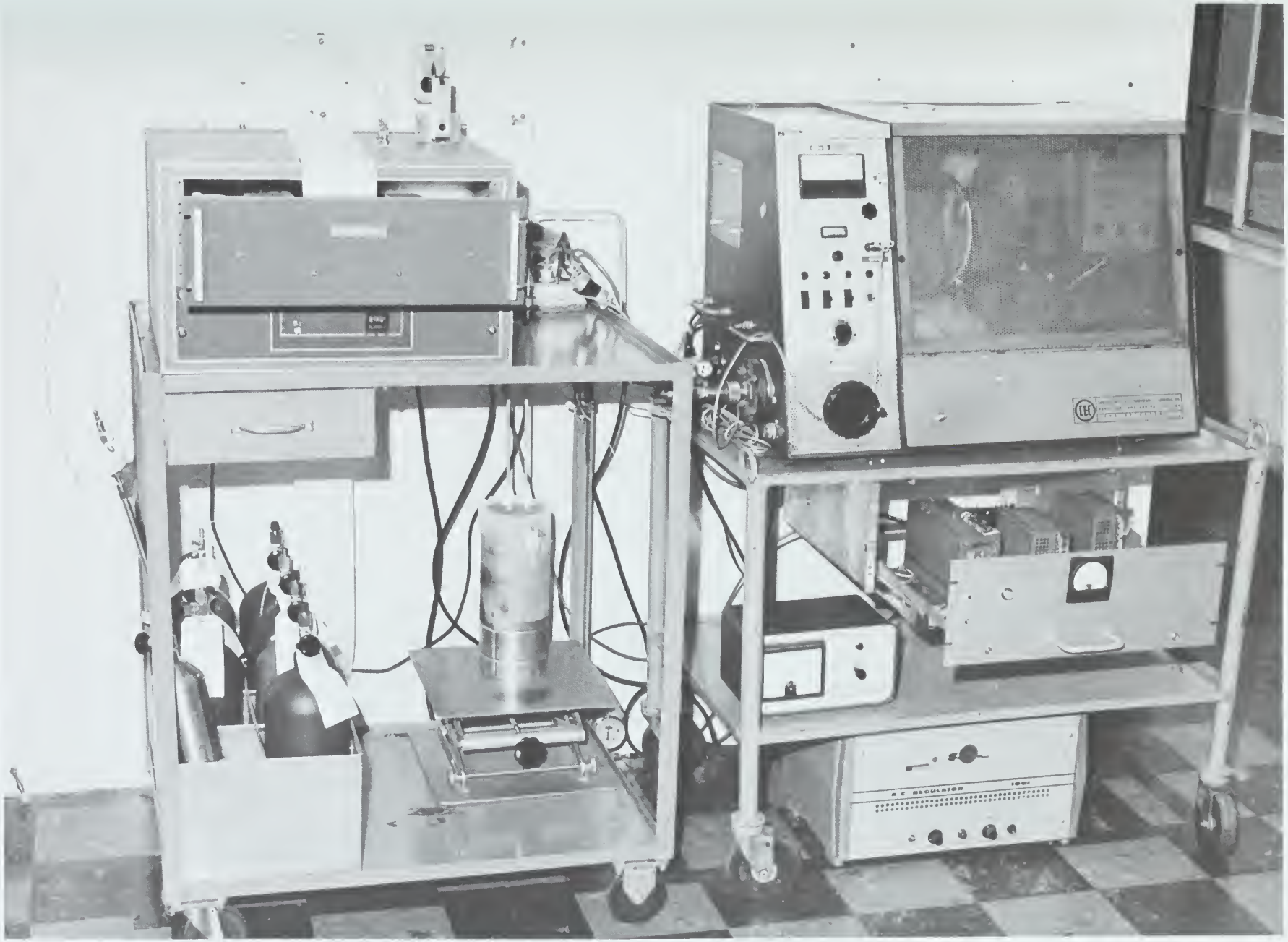

FIGURE 3. – Photograph of Mass Spectrometer System.

EXPERIMENTAL PROCEDURES

Instrument Preparation

The procedures used for startup of the mass spectrometer were as follows. With charcoal trap E connected as shown in Figure 1, valve 3 was closed and power to vacuum pump J and diffusion pump K was switched on. After a 15-min period to allow the diffusion pump to reach its operating temperature, vacuum gauge G was switched on. Cold trap F was then filled (5 cm from top) with liquid nitrogen, and valve 3 was opened to evacuate the charcoal trap. When the pressure (as indicated by G) was below 0.01 Pa, power to ion source H and temperature controller M was switched on. The ionizing current and accelerator voltage of the ion source were then set at 25 μA and 70 Vdc, respectively. Power to vacuum gauge G was then switched off, and the instrument was allowed 1 h for temperature stabilization.

During the 1-h stabilization period, the charcoal in trap E was reactivated by heating it while under vacuum. The procedure was as follows. With valve 3 open, the the charcoal-filled "bulb" of the trap was heated at 200° C for 5 min using a 50-W mantle heater (Briscoe Manufacturing). The temperature of the heater was manually controlled using a variable autotransformer. After the 5-min bakeout was completed, the heater was removed and the trap allowed to cool to room temperature. The liquid nitrogen filled dewar was then raised so that the liquid level was about 5 cm above the level of the charcoal.

After the 1-h stabilization period was completed, the charcoal was conditioned with 12 injections of crude helium (about 70 pct helium and 30 pct nitrogen). The conditioning injections were performed at the rate of three injections per 12-min period, the same rate at which the standard-sample-standard series is performed when conducting sample analyses.

Analysis of Samples

The flow of the helium calibration standard and the sample to be measured was adjusted to between 10 and 25 mL/min by opening valves 10 and 8 and using a hand-held rotameter to monitor the flow rate. With the standard and sample supply lines connected to the inlet ports as shown in Figure 1, a "Start" command was keyed into the integrator to initiate the sequence of integrator commands shown in Table 1. This series of commands was used to set integration parameters and to operate valves 1 and 2 to produce a standard-sample-standard analysis sequence. Valve 7 was used to stop the flow of gas through the sample valve chamber about 3 sec before injection occurred. Thus, the gas sample in the chamber was at atmospheric pressure when the injection was performed. The integration parameters that remain constant throughout the sequence are given in Table 2.

TABLE 1. - Time-programmed integrator commands for valve sequencing and peak quantization.

Time-Programmed Command*	Time of Execution, min	Action of Executed Command**
START	0.00	Sequence of commands is begun.
EXT 5	0.01	Valve 1 is actuated to allow helium standard flow to valve 2.
EXT 6	0.47	Helium standard flow to valve 2 is stopped by activation of valve 7.
INTG 0	0.50	Present baseline is immediately as baseline reference point.
INTG 5	0.51	Baseline is extended horizontally from last declared reference point.
EXT 8	0.52	Valve 2 is actuated to admit helium standard to mass spectrometer.
EXT -8	0.92	Air pressure for actuation of valve 2 is relieved.
EXT 7	0.94	Valve 2 is returned to purge position.
EXT -7	0.96	Air pressure for returning valve 2 to purge position is relieved.
EXT -5	0.98	Valve 1 is returned to enable sample flow to be established to valve 2.
EXT -6	1.00	Sample flow to valve 2 is started by deactivation of valve 7.
EXT 6	4.47	Sample flow to valve 2 is stopped by activation of valve 7.
INTG 0	4.50	Present baseline is immediately declared as baseline reference point.
INTG 5	4.51	Baseline is extended horizontally from last declared reference point.
EXT 8	4.52	Valve 2 is actuated to admit sample to mass spectrometer.
EXT -8	4.92	Air pressure for actuation of valve 2 is relieved.
EXT 7	4.94	Valve 2 is returned to purge position.
EXT -7	4.96	Air pressure for returning valve 2 to purge position is relieved.
EXT 5	4.98	helium standard flow to be re-established to valve 2.
EXT -6	5.00	Helium standard flow to valve 2 is re-established by deactivation of valve 7.
EXT 6	8.47	Helium standard flow to valve 2 is stopped by activation of valve 7.

(Continuation of Table 1)

INTG 0	8.50	Present baseline is immediately declared as baseline reference point.
INTG 5	8.51	Baseline is extended horizontally from last declared reference point.
EXT 8	8.52	Valve 2 is actuated to admit helium standard to mass spectrometer.
EXT -8	8.92	Air pressure for actuation of valve 2 is relieved.
EXT 7	8.94	Valve 2 is returned to purge position.
EXT -7	8.96	Air pressure for returning valve 2 to purge position is relieved.
EXT -6	8.98	Helium standard flow to valve 2 is re-established by deactivation of valve 7.
STOP	12.00	Sequence is terminated and digitized peak heights are printed out.

* Integrator commands are for a Hewlett Packard model 3390A reporting integrator.
** References are to valves 1, 2, and 7 in Figure 2.

TABLE 2. - Other integration parameters for quantization and plotting of helium peaks.

Integration Parameter*	Description of Parameter	Parameter Setting
PK WD	Peak width - time width of peak at half height (min)	0.01
THRSH	Threshold - discrimination level for eliminating signal changes regarded as noise (value entered is integer power of 2)	3
ATT 2↑	Attenuation - plot height scale (value entered is integer power of 2)	9
CHT SP	Chart speed - plot width scale (cm/min)	0.5

* The integration parameters are for a Hewlett Packard model 3390A reporting integrator.

An "Automate Runs" options for the integrator was used to cause the standard-sample-standard analysis sequence to be repeated after each printout of the three peaks acquired during a sequence. The peaks were quantized as height counts (1 height count = 1.25 X 10^{-4} mV) by selecting the "Peak Height" mode for integration.

The liquid nitrogen level surrounding the charcoal trap was adjusted to the same point at the beginning of each standard-sample-standard analysis sequence by refilling the dewar to overflowing. The liquid level in the dewar drops approximately 2 cm during the 12-min period required for completion of the analysis sequence.

ACCURACY OF METHOD

The accuracy of the method was determined by analyzing a group of 15 gas samples containing from 29.15 to 95.53 pct helium. The samples had previously been analyzed using the Emerson/Kaplan method. A comparison of the analysis results is given in Table 3. A sample gas (No. 1) containing almost 5 pct hydrogen could be analyzed without detectable interference from the hydrogen impurity.

TABLE 3. - Comparison of helium analyses obtained using the mass spectrometer and Emerson/Kaplan methods.

Sample Number and Description	Mass Spectrometer Method, pct He	Emerson/Kaplan Method, pct He
1. Helium standard: 86.50 pct helium, 4.73 pct hydrogen, 4.37 pct methane, and 4.40 pct argon	86.61±0.03	86.50
2. Helium upgrader product	95.43±0.11	95.53
3. Helium standard: 29.15 pct helium, 30.77 pct nitrogen, and 40.08 pct methane	29.20±0.05	29.15
4. Crude helium	64.07±0.04	64.08
5. Crude helium	70.52±0.03	70.56
6. Crude helium	73.79±0.05	73.81
7. Crude helium	72.49±0.09	72.47
8. Crude helium	70.48±0.11	70.46
9. Crude helium	71.00±0.05	70.98
10. Crude helium	69.70±0.06	69.79
11. Crude helium	69.90±0.11	69.86
12. Crude helium	68.56±0.02	68.60
13. Crude helium	68.30±0.02	68.33
14. Crude helium	64.22±0.04	64.21
15. Crude helium	70.42±0.07	70.38

The mass spectrometer method results are the means for three successive analyses, and the values for the Emerson/Kaplan method are the means obtained for two successive analyses. The mass spectrometer method results were found to agree with the Emer-

son/Kaplan method results within the analytical precision of about ±0.1 pct. The accuracy of the method is considered to be the same as the precision since pure helium is used as the calibration standard. The method was found to be linear over the investigated range of 29.15 to 95.53 pct helium.

CONCLUSIONS

The newly devised mass spectrometer method described in this report is useful for determining helium in the 30- to 100-pct range. The method provides additional analytical capability for determining the helium content of pipeline crude helium (about 70 pct helium) that enters and leaves the Bureau of Land Management's crude helium storage reservoir located near Amarillo, Texas. The method is also useful for certifying percent-range helium standards that are prepared in the laboratory.

The accuracy of the method is within ±0.1 pct (absolute). The presence of approximately 5 pct hydrogen in a test gas sample had no detectable effect on the helium result. Since such a small volume of sample gas (0.1 μL) is admitted to the liquid-nitrogen-cooled charcoal adsorbent trap at each injection, regeneration of the adsorbent is not required during an 8-h workday. The method was demonstrated to be linear over the investigated range of 29.15 to 95.53 pct helium. Sample analyses can be performed at the rate of 1 analysis per 12-min period.

APPENDIX

The circuits that were used to replace the original electrometer and ion-source control circuits in the CEC 24-120A helium leak detector mass spectrometer are diagrammed in Figures 4 and 5, respectively. The circuits were assembled using commercially available components. Lists of components and their specifications for the electrometer and ion-source control circuits are given in Tables 4 and 5, respectively.

The electrometer circuit (Figure 4) utilizes an operational amplifier (A) for ion current amplification. The amplifier is used in a picoampere current-to-voltage converter inverting configuration. The feedback resistance (R_1) value of 500 GΩ was selected to achieve an output of about 0.5 Vdc with a 100 pct helium sample. Acceptable outputs for low-percent helium samples can be achieved by selecting values for R_1 that are greater than 500 GΩ.

The amplifier-zeroing portion of the circuit is composed of resistors R_3, R_4, R_5, R_8, and R_9, and potentiometer P_2, and capacitors C_2 and C_3. Zero drift of the amplifier is minimized by using a capacitor having a low temperature coefficient for C_2. Resistor R_2 is used to limit the flow of current to the noninverting input (pin 3) of the amplifier if C_2 is fully charged when the circuit is initially powered up. Diodes D_1 and D_2 and capacitors C_4 and C_5 protect the amplifier from voltage spikes. Attenuation of the output signal is accomplished using the voltage divider consisting of resistors R_6 and R_7, potentiometer P_1, and switch S. For high-percent helium samples, P_1 is adjusted to 80 pct of its maximum resistance value and S is set at the "X 10" position.

The portion of the circuit shown enclosed by dotted lines in Figure 4 was installed on the electrometer circuit board supplied by the instrument manufacturer. The circuit board is housed in a 6 X 9 X 18 cm metal case that is located near the mass spectrometer's ion source (Figure 1). To further minimize drift caused by temperature changes, the circuit board housing was insulated using a 2.5-cm-thick layer of foam rubber sheeting.

The ion-source control circuit (Figure 5) was designed to provide a constant ionizing current by regulating direct current through the mass spectrometer filament. The circuit provides adjustment and control of the ionizing current up to 150 μA; however, the upper limit of ionizing current can be extended by using resistances of less than 50 kΩ for resistor R_4.

The circuit utilizes an operational amplifier (A) and two transistors (Q_1 and Q_2) for control of current through the mass spectrometer filament. Electron flow from the filament to the anode (ionizing current) causes a sensing voltage to be developed across R_4 and at pin 5 (noninverting input)of the amplifier. The difference between the voltage at pin 5 and the set-point voltage supplied from the wiper of potentiometer P_1 at pin 4 is amplified. The output of the amplifier at pin 10 controls controls the current through transistor Q_1 and, likewise, through transistor Q_2 and the filament. The control of current through the filament regulates

the temperature of the filament and the rate at which electrons are emitted. Thus, the voltage developed at pin 5 as a result of the electron flow from the filament to the anode and through resistor R_4 occurs to such an extent that the set point voltage at pin 4 is equaled.

The circuit is phased in such a manner that a random increase in ionizing current will cause the sensing voltage at pin 5 of the amplifier to become more negative relative to circuit ground. When this occurs, the output from the amplifier becomes less positive, thereby causing transistors Q_1 and Q_2 to be less conductive. As transistor Q_2 becomes less conductive, current through the filament is reduced, thereby reducing the temperature of the filament. Thus, the ionizing current is reduced toward the control set point. The converse of the above description occurs when there is a random decrease in ionizing current. By adjusting potentiometer P_1, a different ionizing current can be established.

Transistor Q_1 was selected for use in the circuit based on its ability to match the relatively low current output of the amplifier and to provide adequate current for driving Q_2. The current gain for Q_1 as used in the circuit is calculated to be 135. The heat sink used with Q_1 has a maximum temperature rise of 25° C/W.

Transistor Q_2 was selected for its 150-W power rating. This rating provides an adequate safety factor when considering that approximately 11 W is dissipated by Q_2 when a 4-A filament current flows through it. As used in the circuit, the current gain of Q_2 is calculated to be 60. The heat sink for Q_2 has a maximum temperature rise of 0.5° C/W.

Diode D_1 was installed to protect the amplifier if the ion-source anode is shorted to ground. Diodes D_2 and D_3 were installed to protect the amplifier from voltage spikes that might inadvertently be picked up at the output.

Power supplies PS_1, PS_2, PS_3, and PS_4 are used to furnish voltages to the ion-source anode, filament, accelerator, and the operational amplifier, respectively. The accelerator voltage is set at 70 Vdc above circuit ground using potentiometer P_2.

The pilot light was installed in parallel with the filament to indicate filament operation. The light glows dimly under control conditions but glows brightly when the filament is open. The microampere meter indicates the value of the ionizing current.

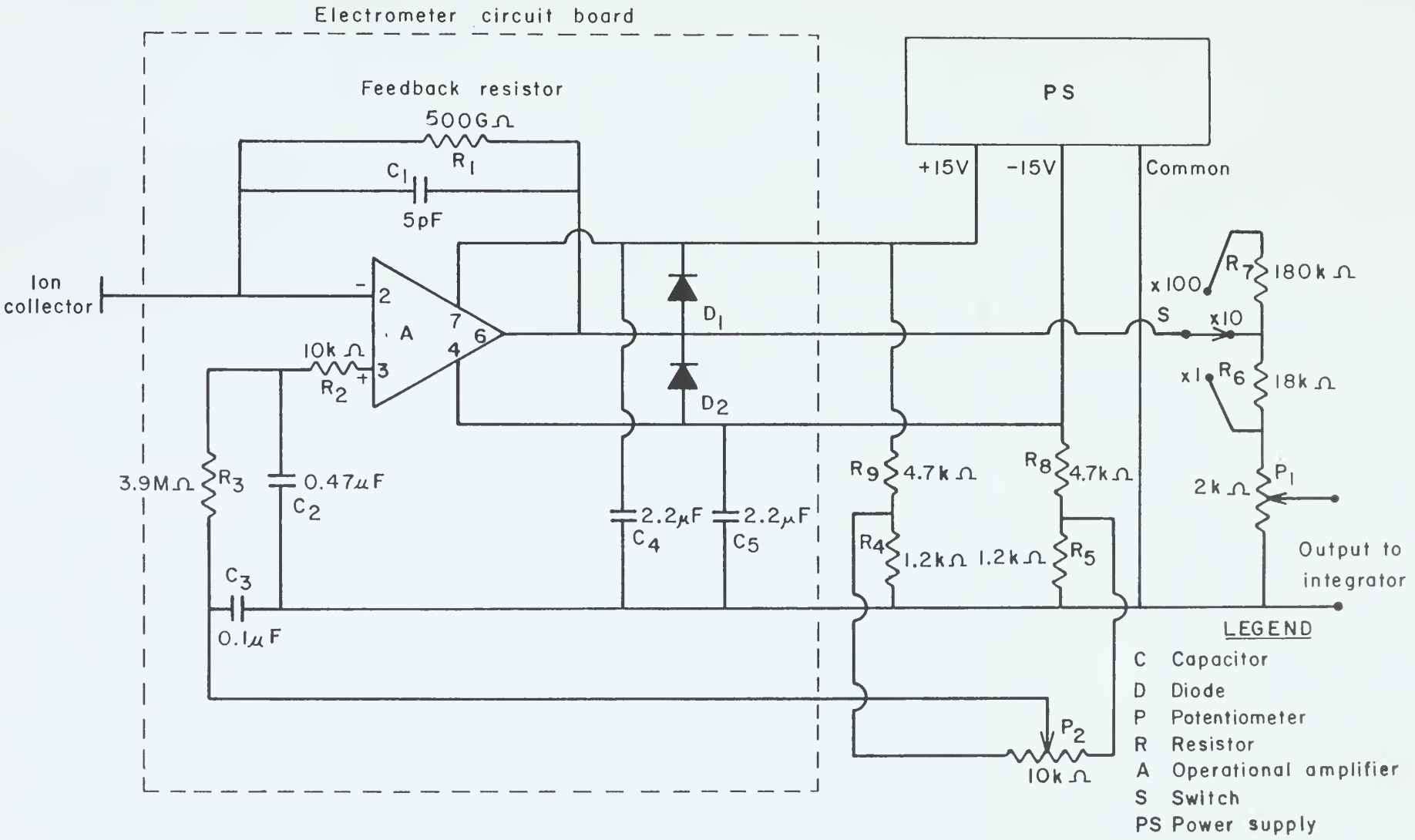

FIGURE 4. – Schematic diagram of mass spectrometer electrometer circuit.

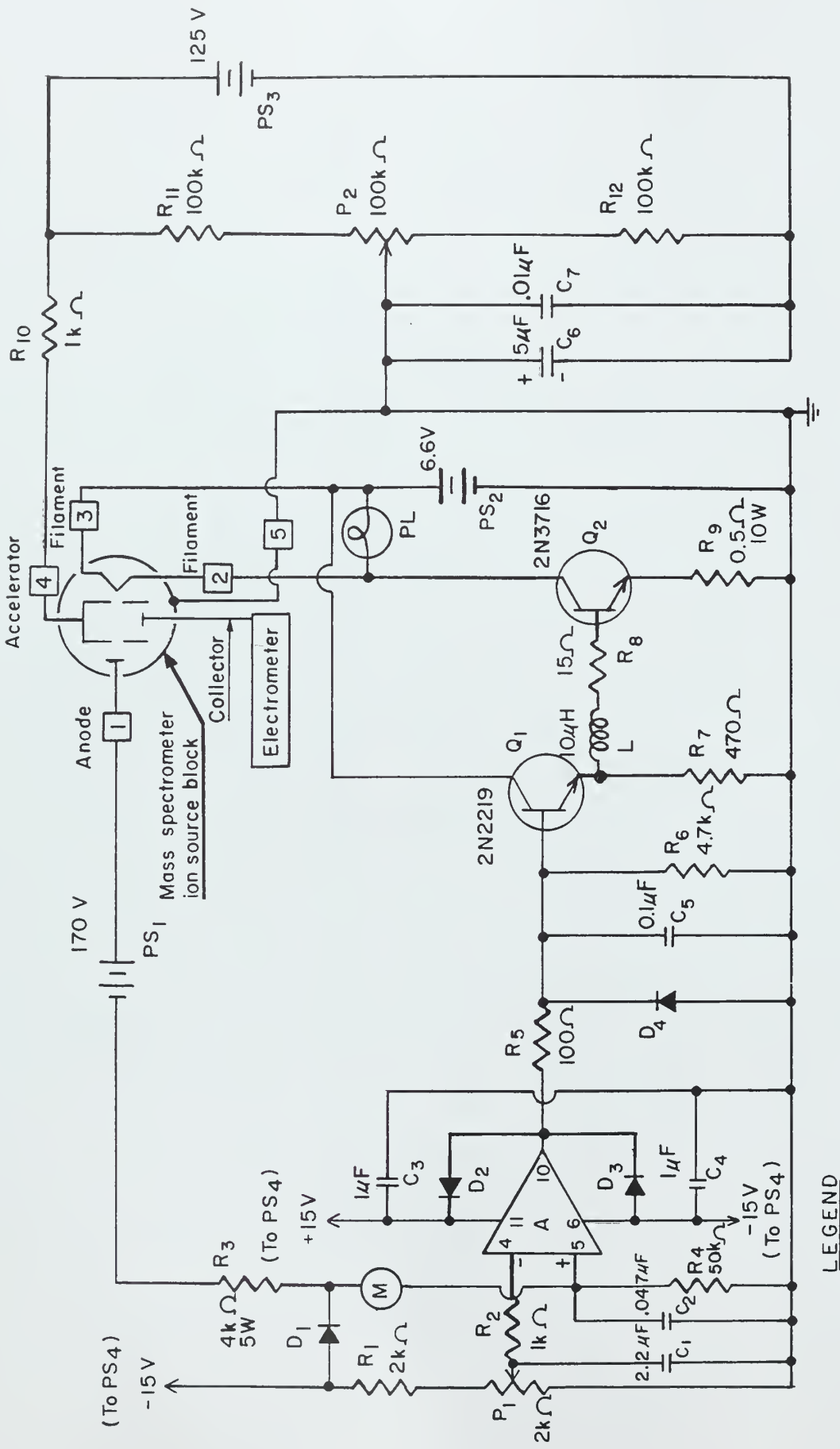

FIGURE 5. – Schematic diagram of mass spectrometer ion–source control circuit.

TABLE 4. - List of components and specifications for electrometer circuit shown in Figure 4.

Component		Specifications
A	operational amplifier	Analog Devices model AD515LH
C_1	capacitor	5 pF, 25 Vdc, electrolytic type
C_2	capacitor	0.47 µF, 50 Vdc, metalized-polycarbonate type with low temperature coefficient
C_3	capacitor	0.1 µF, 25 Vdc, ceramic type
C_4	capacitor	2.2 µF, 25 Vdc, electrolytic type
C_5	capacitor	2.2 µF, 25 Vdc, electrolytic type
D_1	diode	type IN4002
D_2	diode	type IN4002
P_1	potentiometer	2 kΩ, 10-turn, temperature coefficient ±20 ppm/°C
P_2	potentiometer	10 kΩ, 10-turn, temperature coefficient ±20 ppm/°C
R_1	resistor	500 GΩ, glass-encapsulated, Victoreen Instruments, type RX-1
R_2	resistor	10 kΩ, 0.25 W
R_3	resistor	3.9 MΩ, 0.25 W
R_4	resistor	1.2 kΩ, 0.25 W
R_5	resistor	1.2 kΩ, 0.25 W
R_6	resistor	18 kΩ, 0.25 W
R_7	resistor	180 kΩ, 0.25 W
R_8	resistor	4.7 kΩ, 0.25 W
R_9	resistor	4.7 kΩ, 0.25 W
S	switch	single-pole, three-position
PS	power supply	dual, +15 Vdc and -15 Vdc, Calex Manufacturing Co., model 22-100

TABLE 5. - List of components and specifications for ion-source control circuit shown in Figure 5.

Component		Specifications
A	operational amplifier	Precision Monolithics, model OP-07-EY
C_1	capacitor	2.2 µF, 25 Vdc, electrolytic type
C_2	capacitor	0.047 µF, 25 Vdc, ceramic type
C_3	capacitor	1 µF, 25 Vdc, tantalum type
C_4	capacitor	1 µF, 25 Vdc, tantalum type
C_5	capacitor	0.1 µF, 25 Vdc, ceramic type
C_6	capacitor	5 µF, 200 Vdc, electrolytic type
C_7	capacitor	0.01 µF, 200 Vdc, ceramic type
D_1	diode	type IN4004, low-leakage tested
D_2	diode	type IN4002
D_3	diode	type IN4002
D_4	diode	type IN4002
L	inductor	10 µH
M	meter	0-200 µA
P_1	potentiometer	2 kΩ, 10-turn, temperature coefficient ±20 ppm/°C
P_2	potentiometer	100 kΩ, 10-turn, temperature coefficient ±20 ppm/°C
PL	pilot light	incandescent, no. 47
PS_1	power supply	adjustable, 125-175 Vdc, Lambda Electronics, model LDS-Y-150
PS_2	power supply	adjustable, 5-9 Vdc, Lambda Electronic, model LDS-W-01
PS_3	power supply	adjustable, 125-175 Vdc, Lambda Electronics, model LDS-Y-150

PS_4	power supply	dual, +15 Vdc and -15 Vdc, Calex Manufacturing Co., model 22-100
Q_1	transistor	NPN, type 2N2219
Q_2	transistor	NPN, type 2N3716
R_1	resistor	2 kΩ, 0.25 W, temperature coefficient ±8 ppm/°C
R_2	resistor	1 kΩ, 0.25 W, temperature coefficient ±8 ppm/°C
R_3	resistor	4 kΩ, 5 W
R_4	resistor	50 kΩ, 0.25 W, temperature coefficient ±8 ppm/°C
R_5	resistor	100 Ω, 0.25 W
R_6	resistor	4.7 kΩ, 0.25 W
R_7	resistor	470 Ω, 0.25 W
R_8	resistor	15 Ω, 5 W
R_9	resistor	0.5 Ω, 10 W
R_{10}	resistor	1 kΩ, 0.25 W
R_{11}	resistor	100 kΩ, 0.25 W, wire-wound type
R_{12}	resistor	100 kΩ, 0.25 W, wire-wound type

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1. AGENCY USE ONLY *(Leave blank)*	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	November 1996	Final

4. TITLE AND SUBTITLE

A Mass Spectrometer Method for Determining Percent-Range Helium in Gaseous Mixtures

5. FUNDING NUMBERS

6. AUTHOR(S)

Philip W. Holland

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

U.S. Department of the Interior
Bureau of Land Management -- Helium Operations
801 South Fillmore, Suite 500
Amarillo, Texas 79101-3545

8. PERFORMING ORGANIZATION REPORT NUMBER

BLM/HE/ST-97/001+3700

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT

12b. DISTRIBUTION CODE

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QL 84.2 .L35 no. 398
ID: 88057135
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sure peak." The digitized peak of the
a high-purity helium calibration
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at 30 to 100 percent helium.

14. SUBJECT TERMS

Helium
Mass spectrometer
Gaseous mixtures
Percent-range helium

15. NUMBER OF PAGES

20

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
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12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

The Bureau of Land Management's Helium Operations office has developed a mass spectrometer method to determine percent-range helium in gaseous mixtures. Activated coconut charcoal at liquid nitrogen temperature is used to adsorb components other than helium in the mixture. A modified helium leak detector mass spectrometer is then used to detect the resulting helium"pressure peak." The digitized peak of the unknown sample is compared directly to that of a high-purity helium calibration standard. This method has been demonstrated to be accurate to within plus or minus 0.1 percent over the concentration range of about 30 to 100 percent helium.

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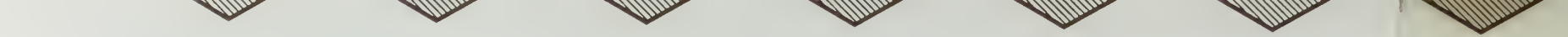
Unclassified	Unclassified	Unclassified	UL



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